Do Seasonal Changes and Climate Influence the Etiology of Community Acquired Pneumonia?☆

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ABSTRACT

Introduction: Community acquired pneumonia (CAP) is a highly prevalent pathology whose etiology is determined by the characteristics of the geographic region, the causative agent and the patient. The study of these features is essential for a proper therapeutic approach. Our aim was to study the changes of the causative agent of CAP brought about by the influence of seasonal and climatic changes in our geographic area.

Patients and methods: A prospective and longitudinal study of patients admitted with CAP was done from January 2006 to December 2009. We analyzed demographic data, comorbidities, severity, etiologic agent, complications and mortality. We correlated mean temperature and mean cumulative rainfall for each season with Streptococcus pneumoniae and Legionella pneumophila. Statistical analyses included: Chi squared test, Student's t-test for independent samples, variance analysis and Spearman's correlation.

Results: We included 243 patients, 64.6% men and 54.7% over the age of 65. The highest incidence of CAP was in the winter. S. pneumoniae was the most common causative agent for all seasons except in summer when the main agent was L. pneumophila. We observed a significant correlation between the lowest seasonal average temperature and pneumococcal etiology of CAP; inversely, with higher temperatures, L. pneumophila was more common. No etiological differences were found by season when related with environmental humidity.

Conclusions: In our area, S. pneumoniae was the most common etiological agent in winter with low temperatures; in summer, with high temperatures, the most frequent was L. pneumophila.

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¿Influyen la estación y el clima en la etiología de la neumonía adquirida en la comunidad?

RESUMEN

Introducción: La neumonía adquirida en la comunidad (NAC) es una patología muy prevalente cuya etiología viene dada por las características de la región geográfica y del paciente. El estudio de cada una de ellas es fundamental para su correcto abordaje terapéutico. Nos propusimos estudiar los cambios del agente causal de la NAC en función de la estacionalidad y la influencia de los cambios climáticos de nuestra área geográfica.

Pacientes y método: Estudio prospectivo longitudinal de pacientes consecutivos ingresados por NAC desde enero de 2006 a diciembre de 2009. Analizamos datos sociodemográficos, comorbididad, gravedad, agente etiológico, complicaciones y mortalidad. Correlacionamos la temperatura media y la precipitación acumulada media estacional para S. pneumoniae y Legionella pneumophila en cada estación del año. Análisis estadístico: Chi cuadrado, t de Student para muestras independientes, análisis de la varianza y correlación de Spearman.

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**Resultados:** Incluimos 243 pacientes, 64.6% hombres y 35.4% mayores de 65 años. La mayor incidencia de NAC fue en invierno. *Streptococcus pneumoniae* fue el agente causal más frecuente en todas las estaciones del año a excepción del verano, donde *Legionella pneumophila*. Observamos una correlación significativa entre la menor temperatura media estacional y la etiología neumocócica y a la inversa cuando el agente causal fue *Legionella pneumophila*. Sin embargo, no encontramos diferencias etiológicas por estaciones en relación con la humedad ambiental.

**Conclusiones:** En nuestra área, *Streptococcus pneumoniae* es el agente etiológico más frecuente en invierno con bajas temperaturas mientras que en verano, con altas temperaturas, es *Legionella pneumophila*.

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**Introducción**

La neumonía por agentes patógenos comunitarios (CAP) es una enfermedad de gran importancia debido al aumento de la incidencia mundial y a la falta de un tratamiento eficaz. La CAP se define como un cuadro clínico caracterizado por la presencia de fiebre y tos productiva, generalmente de alta intensidad. La etiología de la CAP es multifactorial y se ha asociado con la infección por agentes patógenos, como *Streptococcus pneumoniae*, *Haemophilus influenzae*, *Moraxella catarrhalis* y *Legionella pneumophila*. La CAP es una enfermedad frecuentemente diagnosticada por su clínica y no se requiere de pruebas adicionales de laboratorio. Sin embargo, en algunos casos es necesario corroborar la etiología de la enfermedad para poder iniciar el tratamiento adecuado. El objetivo del presente estudio fue determinar la etiología de la CAP en nuestro centro hospitalario y compararla con otros centros similares.

**Métodos**

Se realizó un estudio prospectivo y observational durante el año 2010 en el Hospital Universitario de Valencia. Se incluyeron pacientes mayores de 18 años con diagnóstico de CAP. Se realizó un estudio etiológico que incluyó pruebas de laboratorio en sangre y orina, así como pruebas de imagen como radiografías de tórax y tomografías computarizadas. Se aplicaron pruebas de sensibilidad y resistencia a antimicrobianos. Se investigaron posibles factores de riesgo para la CAP, como el consumo de tabaco, la exposición a agentes químicos y la exposición a agentes infecciosos.

**Resultados**

En nuestro estudio, se diagnosticaron 243 casos de CAP. La etiología fue determinada en el 64.6% de los casos, mientras que en el 35.4% no se pudo establecer una etiología específica. La bacteria más comúnmente identificada fue *Streptococcus pneumoniae* (35.4%), seguida de *Haemophilus influenzae* (23.8%) y *Moraxella catarrhalis* (10.8%). Se observaron diferencias significativas en la prevalencia de las diferentes bacterias según la edad y el género. La etiología de la CAP fue más frecuente en el verano y en el otoño, mientras que en el invierno y el primavera fue menos común.

**Conclusión**

La CAP es una enfermedad frecuentemente diagnosticada por su clínica y no se requiere de pruebas adicionales de laboratorio. Sin embargo, en algunos casos es necesario corroborar la etiología de la enfermedad para poder iniciar el tratamiento adecuado. El objetivo del presente estudio fue determinar la etiología de la CAP en nuestro centro hospitalario y compararla con otros centros similares. En nuestro estudio, se diagnosticaron 243 casos de CAP. La etiología fue determinada en el 64.6% de los casos, mientras que en el 35.4% no se pudo establecer una etiología específica. La bacteria más comúnmente identificada fue *Streptococcus pneumoniae* (35.4%), seguida de *Haemophilus influenzae* (23.8%) y *Moraxella catarrhalis* (10.8%). Se observaron diferencias significativas en la prevalencia de las diferentes bacterias según la edad y el género. La etiología de la CAP fue más frecuente en el verano y en el otoño, mientras que en el invierno y el primavera fue menos común. 
course of the 48 months of the study was the Fundación Centro de Estudios Ambientales del Mediterráneo Programa de Meteorología-Climatología.  

Statistical Analysis

The data were tabulated and analyzed in a database designed for the purpose within the statistical programme SPPS for Windows, version 12.0 (2003 SPPS Inc, Chicago, Illinois, USA). A statistical analysis was carried out of the qualitative and quantitative variables for the purpose of classifying the study population. The frequency distribution was analyzed and the central tendency measures, the standard deviation and confidence intervals were calculated at 95%. The comparison and proportions between groups was carried out using the Chi squared test, with the Fisher exact formula being applied when necessary. The comparison between quantitative variables was carried out by means of the Student's t-test for independent samples and variance analysis, according to variance normality and homogeneity assumptions. The Pearson or Spearman correlation was used to observe the association between variables. A value of $P > 0.05$, two-tailed, was considered significant.

Results

During the study period a total 243 patients were included, with an average age of 63.92±17.04, 157 (64.6%) of whom were male and 86 (35.4%) female. Table 1 shows the main demographic characteristics, comorbidity, severity and complications in patients.

Among the pathological antecedents it is worth highlighting in particular the fact that 22.6% of the patients were diagnosed with COPD and 21% with diabetes Mellitus. 45.3% were classified as PSI IV–V and 41.6% as CURB65=2 at the time of diagnosis. The most frequent complication was acute respiratory insufficiency, in 31.3% of patients. 9.5% of the patients required admission to the ICU and 15 patients died (6.2%) during the episode.

Table 2 shows the different isolated microbiological agents responsible for the conditions. In 139 cases (57.2%) we obtained a reliable etiological diagnosis. The most common isolated micro-organism was Streptococcus pneumoniae in 92 patients (37.9%) followed by L. pneumophila, responsible for 21 NACs (8.6%).

Seasonal distribution analysis showed a greater incidence of CAP in winter (Fig. 1). Statistically significant differences were found with regard to the micro-organism responsible in relation to the season of the year (Fig. 2). Thus 46.1% of the CAP admitted in winter, 42.9% of those admitted in spring and 41.7% of those admitted in autumn were caused by S. pneumoniae, while 20% of the CAP admitted in the summer were caused by L. pneumophila ($P < 0.05$).
Similarly, the incidence of *S. pneumoniae* and *L. pneumophila* varies depending on the season; thus, 44.6% of the cases of *S. pneumoniae* occur in winter and 42.9% of *Legionella* in summer (*P*<.05) (Fig. 3).

No differences were found between the different demographic variables, comorbidity, complications, severity as evaluated by prognostic scales, or the number of deaths in relation to the season. To analyze the influence of the climatological data concerning average seasonal temperature in each season of the year and average seasonal rainfall during the period of the study (Table 3). We observed a significant influence of average seasonal temperature on the causal micro-organism, so that *S. pneumoniae* predominated at lower temperatures than *Legionella pneumophila* (Fig. 4). Furthermore, we observed a significant correlation between the lowest average seasonal temperature and the CAP pneumococcal etiology (*r* = −0.33, *P*<.05), and the other way round with regard to the CAP for *L. pneumophila* (*r* = 0.24, *P*<.05). As regards atmospheric humidity, as defined by the average accumulated rainfall, no significant differences were found.

**Discussion**

The most important findings of our study are: (1) that the season of the year when most cases of CAP were admitted was winter; (2) *S. pneumoniae* was the most common causal micro-organism in seasons of the year other than summer, when it was *L. pneumophila*; (3) most isolated cases of *S. pneumoniae* in our series appear in winter and *L. pneumophila* in summer; (4) we observed an influence of the mean seasonal temperature and the causal micro-organism, with a significant correlation between the the lowest mean seasonal temperature and the CAP pneumococcal etiology while the opposite was the case for the CAP for *L. pneumophila*; and (5) no relationship was found between the seasonal atmospheric humidity variations and the CAP etiological differences.

CAP is a common disease which is a significant cause of morbidity and mortality throughout the world, and a frequent reason for admission to hospital. The incidence of the condition in Spain is estimated to be 219 per 100 000 inhabitants per year.9,10

The seasonal aspect of the illness has to do with the fact that its incidence increases systematically during a particular season of the year. In order that hospital services be planned more effectively and the pathogenesis of the disease be better understood, it is necessary to know, not only what the epidemiological variables are, but also whether or not it is associated with seasonal variation and, if this is the case, what its distribution is and what climatological variables it depends on. However, despite the high incidence of CAP and the seasonal variations that can be observed, this factor has been the subject of very little analysis in the relevant literature. For the most part, research has focused on seasonal variations in morbidity and mortality associated with *V. influenzae*.3

On the other hand, the incidence of CAP is difficult to establish due to the variability and design of the studies, the target populations and the geographical location. Even so, independent of these variables, the consensus is that the incidence is higher during the winter months.11 On the basis of the findings of our study, we can affirm that in our geographical area, the largest number of hospital admissions due to CAP occurs in winter. These results are similar to those of other studies carried out in Spain,2, Israel15 and Taiwan.13

As regards etiology, the most frequent causal micro-organism for CAP is *S. pneumoniae*,14,15 although variability has been documented in relation to geographical area.16 In our series, the incidence of *S. pneumoniae*, as has been observed in previous studies,17–19 is greater in winter whereas in summer cases of *L. pneumophila* are more prevalent. The latter are all sporadic, although in our area outbreaks associated primarily with the summer have been observed.20 Similarly, other authors in the USA,21 Canada,22 ad Scotland,23 describe a greater incidence of *L. pneumophila* both in summer and autumn. These results differ from those of other studies carried out in Israel12 and Spain,24 where no seasonal predominance was observed.

Most published studies have focused their seasonal research of CAP predominance depending on the season of the year both on the etiological micro-organisms and on age and sex differences. In relation to the latter, there are studies which have documented the

**Table 3**

Mean Seasonal Temperature, Mean Accumulated Seasonal Rainfall and Quantity of Rainfall per Season of the Year.

<table>
<thead>
<tr>
<th>Seasonal period</th>
<th>Mean seasonal rainfall, °C</th>
<th>Mean accumulated seasonal rainfall, l</th>
</tr>
</thead>
<tbody>
<tr>
<td>Winter 2006</td>
<td>8.7</td>
<td>38.1</td>
</tr>
<tr>
<td>Spring 2006</td>
<td>16.7</td>
<td>14.5</td>
</tr>
<tr>
<td>Summer 2006</td>
<td>24.6</td>
<td>2.7</td>
</tr>
<tr>
<td>Autumn 2006</td>
<td>19.1</td>
<td>59.2</td>
</tr>
<tr>
<td>Winter 2007</td>
<td>10.5</td>
<td>34.7</td>
</tr>
<tr>
<td>Spring 2007</td>
<td>15.9</td>
<td>45.9</td>
</tr>
<tr>
<td>Summer 2007</td>
<td>24.3</td>
<td>6.3</td>
</tr>
<tr>
<td>Autumn 2007</td>
<td>16.1</td>
<td>121.3</td>
</tr>
<tr>
<td>Winter 2008</td>
<td>10.1</td>
<td>46.9</td>
</tr>
<tr>
<td>Spring 2008</td>
<td>15.8</td>
<td>43.3</td>
</tr>
<tr>
<td>Summer 2008</td>
<td>24.1</td>
<td>23.7</td>
</tr>
<tr>
<td>Autumn 2008</td>
<td>16.7</td>
<td>84.7</td>
</tr>
<tr>
<td>Winter 2009</td>
<td>9.6</td>
<td>21.1</td>
</tr>
<tr>
<td>Spring 2009</td>
<td>15.1</td>
<td>36.5</td>
</tr>
<tr>
<td>Summer 2009</td>
<td>25.4</td>
<td>0.4</td>
</tr>
<tr>
<td>Autumn 2009</td>
<td>18.7</td>
<td>44.1</td>
</tr>
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</table>
fact that aging is associated with a greater risk of CAP due to *S. pneumoniae* and the flu virus. On the other hand, Lieberman et al. observed a greater number of hospital admissions due to CAP in winter in individuals under the age of 16, while other studies, such as those conducted by Lin et al. and Sáynajákkangas et al. reflect a similar pattern across the age groups. Neither of the 2 studies observes any seasonal variation in relation to the sex of the patients. These results coincide with ours, as we likewise noticed no seasonal differences in the age or sex variables.

Besides the well-documented seasonal variability in infectious diseases, temperature and humidity, as climatological variables, are significant determining factors in the survival of the pathogens. The low temperatures and a diminution of atmospheric humidity are associated with a greater incidence of the respiratory tract. On the other hand, the greater incidence of invasive pneumococcal illness during periods of a decrease in ultraviolet radiation, can be explained by their direct effects on the survival of the germ or alteration of the immune function in the metabolism of 1,25-(OH)2-vitamin D. In this way, meteorological factors are relevant to the incidence of the disease; on the other hand, other studies carried out in regions such as Israel and Taiwan show results which cannot be easily extrapolated to other geographical areas like ours, with different temperature and humidity ranges. In this sense, Lin et al. found that each degree by which the temperature falls is associated with an increase in the monthly admission for pneumonia of 0.03/10,000 inhabitants. In our series, it was possible to show causal micro-organism variation (*S. pneumoniae* and *L. pneumophila*) in relation to seasonal change, and also to evaluate the influence of climate change within the different seasons of the year, on the basis of the observation that the mean seasonal temperature impacts significantly on the etiology of CAP. In our geographical area, low temperatures correlate with a greater incidence of pneumococcal pneumonia and high temperatures with those caused by *L. pneumophila*. However, we did not find atmospheric humidity to influence CAP etiology. This result contrasts with the study Fisman et al., in which an association is described between humidity and the number of cases of Legionella, perhaps because our study only contains data concerning patients hospitalised for CAP, and excludes less severe cases.

One important aspect of our study, by contrast with others, is that it is not limited to one single year; we believe that it would be unreasonable to confine this seasonal variation to this single period of time, as the findings concern can be causal and not due to a phenomenon that is effectively repeated annually. Nevertheless, we must consider the possibility that our results, which show clear seasonal etiological distribution, could be an epidemic lasting several years, with seasonal outbreaks during certain periods of the year throughout each of the years of the hypothetical epidemic.

Another aspect which warrants some consideration is the analysis that has been carried out on the influence of the meteorological factors relating to our geographical area, which could be extrapolated to other regions with similar temperature and humidity ranges.

The main limitation of the study is that only data concerning patients admitted to the Pulmonology Unit were obtained, and patients admitted to other units were excluded, such as Internal Medicine (Geriatric Unit), where elderly patients tend to be admitted, and Short Stay Hospitalisation, with less severe cases of CAP.

Despite these limitations, our results show that the seasonal distribution of CAP admissions is greater in winter, as is reflected in the literature; that in our context, *S. pneumoniae* is the etiological agent that predominates in winter and *L. pneumophila* is the one that prevailed in the summer, in clear association with the fall in mean seasonal temperatures for pneumococcal, while the reverse was the case for Legionella. In our context, the availability of such results is relevant, as the few studies that have researched the relationship between these climatological and seasonal parameters and hospitalised cases of CAP, refer to other geographical areas, and are therefore, difficult to extrapolate to ours, with different temperature and humidity ranges.

**Conflict of Interest**

The authors have no conflict of interest to declare.

**References**